A STUDY OF A. C. RESISTIVITY OF CALCUTTA SOIL*

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ABSTRACT. The paper deals with the a.c. resistivity of soils in and around the city of Calcutta and its variations with temperature and moisture content of the soil.

INTRODUCTION

In a previous communication (Bhattacharyya and Mahanti, 1953) the results of study of d.c. resistivity of soil in and around the city of Calcutta and its variation with time, temperature and humidity were reported. The effect of endosmosis was also ascertained. In the present paper are reported the results of measurement of its a.c. resistivity.

It has been stated (Bhattacharyya and Mahanti, 1953) that all previous workers have studied the a.c. resistivity of Indian soils at only high frequencies. But as the values of electrical constants of a soil are not the same at different frequencies and since the frequency of a.c. power supply in Calcutta is 50 cycles per second, it was thought desirable to obtain data of a.c. resistivity of Calcutta soil at such power frequency.

The method of measurement was the same as that employed for measurement of d.c. resistivity. For the present purpose the a.c. voltage applied across the test samples was of magnitude 120 volts and was taken from an a.c. supply of 220 volts through an auto-transformer.

The same samples of soil as used for the measurement of d.c. resistivity were used, and the same technique also employed in preparing the test samples.

EXPERIMENTAL RESULTS

Table I contains the data of a.c. resistivity of different samples of soil at a room temperature of 30° C and with a moisture content of 15 per cent. For comparison, the data of their d.c. resistivity are also included in the table.

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TABLE I

Soil taken from	a.c. Resistivity (ohm-cm)	d.c. Resistivity (ohm-cm)
East Calcutta (Beliaghata)	2778	3250
Central Calcutta (Science College)	2650	2850
West Calcutta (Dockyard)	1379	1450
North Calcutta (Sinthee)	1375	1415
South Calcutta (Tollygunge)	1350	1400
Ganges Silt	1312	1365

It will be seen from Table 1 that the value of a.c. resistivity of soil of a particular locality is lower than that of its d.c. resistivity. This difference is attributed to the polarisation effect accompanying direct current. Similar results have been obtained also by the previous workers (Higgs, 1930; Smith-Rose, 1934) on soils of other countries.

TIME CURRENT CHARACTERISTICS

A steady a.c. voltage was applied across a sample of soil having a definite value (16 per cent) of moisture content and the reading of the ammeter at suitable intervals was noted until the current attained a constant value. The results are shown graphically in figure 1. It is seen that the current at first increases to a maximum value and then decreases to a minimum. This is unlike what one would

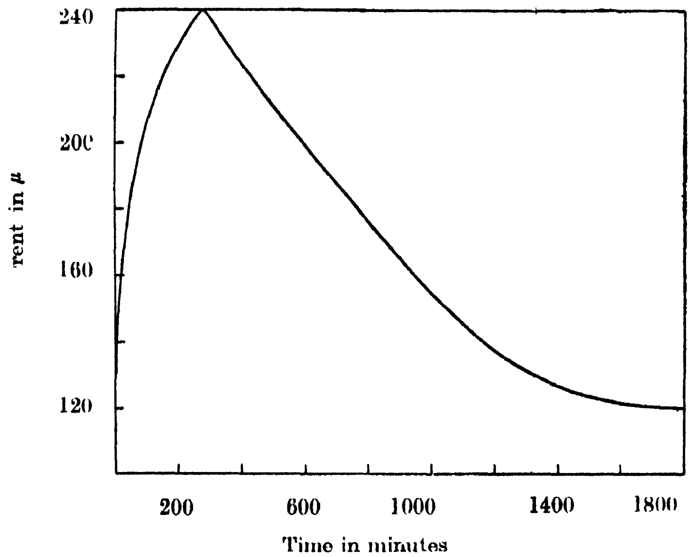

Fig. 1

expect when a current passes through a sample of soil containing many electrolytic salts in its composition since the coefficient of electrical conductivity of such a soil should be positive. But the nature of the curve is found nearly identical with that of the corresponding curve obtained with direct current passing through the sample of soil. In the latter case, the predominance of the heating effect over the effects of polarisation and endosmosis or vice versa determines the total resistance of the sample at any instant. The last two effects tend to increase the resistance of the soil. But with alternating current the polarisation effect is absent. Moreover, as the moisture moves in the direction of the current flow, the effect of endosmosis is also negligible. Hence the nature of the time-current characteristics will depend on the heating effect alone. To confirm this it was thought of interest to study the temperature gradient across the sample when carrying alternating current. For this purpose a sample of soil (Central Calcutta) having a given moisture content (14 per cent) was taken in the experimental cylinder and on its surface three equidistant holes, one at the middle and two near the ends, were bored vertically through its axis. Three sensitive thermometers were introduced into the soil through these three holes. The two outer thermometers would give the temperature of the soil section nearest to the electrodes while the temperature of the middle section would be recorded by the third thermometer. A constant a.c. voltage was applied across the electrodes and the current allowed to flow continuously until it was found to attain a constant value. At suitable intervals the readings of the voltmeter, the ammeter and the thermometer were recorded. Finally when thermometer readings were steady, the percentage of the moisture content of the soil in the immediate neighbourhood of the thermometer bulbs was determined and found to be as shown in Table II.

TABLE II

Position of the thermometer along the tube	Temperature °C	Per cent of moisture content
End 1	45	13.0
Middle	55	11.1
End 2	46	12.9

Curves showing the variations of temperature recorded by each thermometer with time are given in figure 2, which also includes the corresponding values of current flowing through the sample.

Form the curves it is seen that the temperature of each section first rises and then diminishes to a minimum value although temperatures of these sections are different from one another. It is further seen that the temperature of the middle section is always higher than that of each outer section. Electrodes, being in contact with the atmosphere, radiate their heat to the surroundings and the temperature of each soil section adjacent to electrodes is, therefore, of lower value that that of the middle section. A temperature gradient is thus set up in the

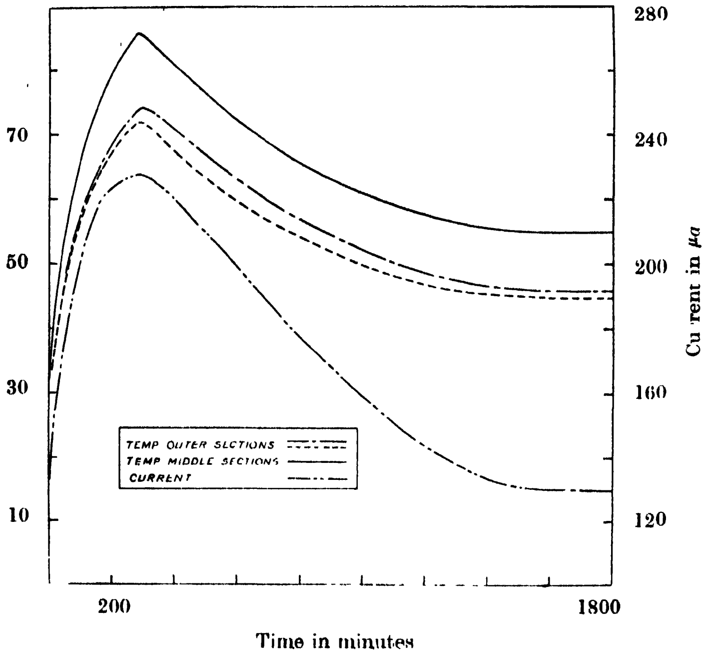

Fig. 2

sample of the soil from the central plane to either electrodes and the moisture moves along this gradient. Thus the distribution of moisture content in the soil is disturbed, the moisture having a tendency to accumulate more near the outer electrodes than at the centre. After sometime heat radiates from the outer surface of the porcelain tube and the temperature of the whole system therefore decreases till a steady state is reached.

The effect of temperature gradient on the current distribution in the body of the soil in the experimental cylinder was also studied. When the applied voltage is kept constant the voltage drop across any section depends on its moisture content as well as on its temperature. The drop across each of the three sections of the sample of soil was obtained in a similar manner as was obtained previously (loc. cit) to study the effect of endosmosis. The results are shown graphically in figure 3. From these curves it is seen that with time the voltage drop across the middle section first decreases and then increases to a maximum value while the drop across each of the outer sections first increases and then diminishes to a minimum. This is due to the fact that a moisture content gradient sets in the soil along with the temperature gradient. At any instant their additive effects, so long the applied voltage remains constant, determine therefore the value of the total resistance of any section and hence the voltage drop across it.

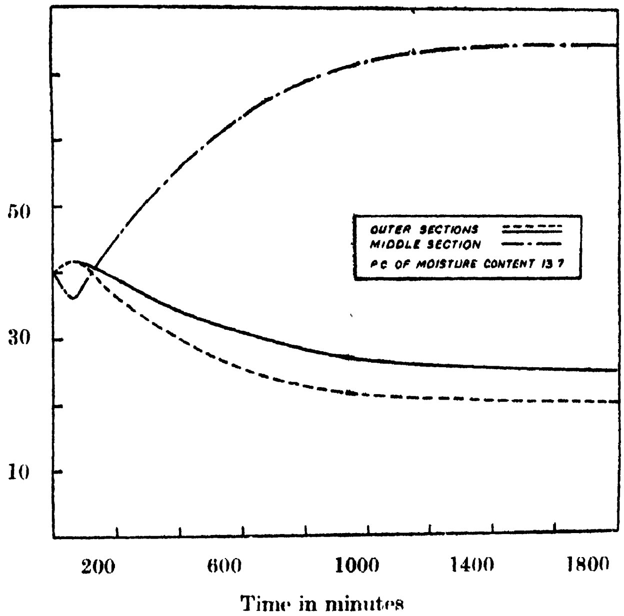

Fig. 3

Effect of moisture content as well as effect of temperature on different soil samples were studied separately and found to yield almost the same results as those obtained in the d.c. measurement, the only difference being that for the same moisture content and for the same temperature, the a.c. resistivity is always lower than the d.c. resistivity.

For ascertaining the effect of polarisation in the soil an experimental arrangement was set up as shown in figure 4. A steady d.c. voltage was applied across a sample of soil of known moisture content and the reading of the ammeter at suitable intervals was noted until the current attained a constant value. Along

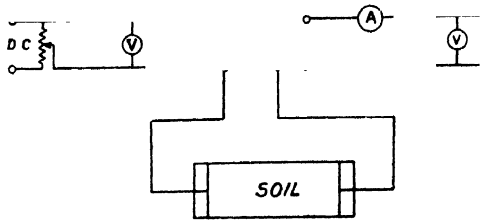

Fig. 4

with each ammeter reading, the temperature of the test sample was also recorded with the help of a sensitive thermometer introduced into it through a hole along the axis of the cylinder. Switch over from d.c. to a.c. was made at regular intervals as quickly as possible and the a.c. ammeter was read. Results are shown graphically in figure 5, which also includes the corresponding values of resistivity, both d.c. and a.c., of the sample. From the figure, it is seen that both d.c. and a.c. resistivity curves show the same characteristics. It is further seen that d.c.

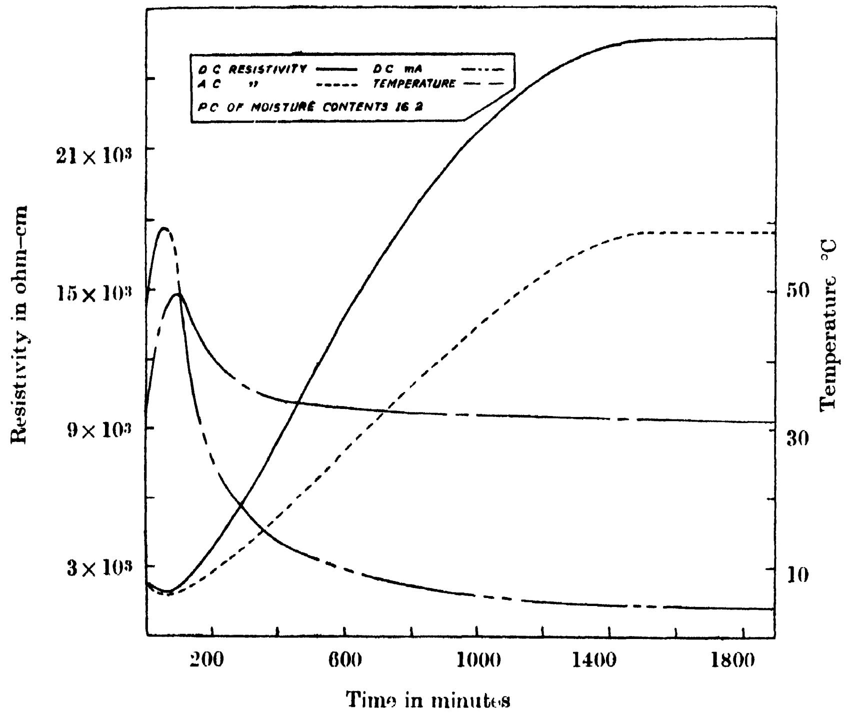

Fig. 5

resistivity increases more rapidly than a.c. resistivity with time but finally they become constant. This difference is attributed to the absence of the effect of polarisation when alternating current is used. So the difference in the values of a.c. and d.c. resistivities may give an idea of the degree of polarisation at any instant. The effect of endosmosis is not taken into account as at any instant the distribution of moisture set up by the flow of direct current will remain unaltered if the readings on a.c. side be taken quickly.

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